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Ottawa Hull K1A 0C9

(21) (A1) 2,180,686
(22) 1996/07/08
(43) 1997/02/10

(51) Int.Cl.[6] C10G 11/18

(19) (CA) APPLICATION FOR CANADIAN PATENT (12)

(54) External Pressurized Closed-Cyclone Apparatus for FCC Unit

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(30) (US) 512,870 1995/08/09

(57) 12 Claims

Notice: This application is as filed and may therefore contain an incomplete specification.

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EXTERNAL, PRESSURIZED CLOSED-CYCLONE APPARATUS FOR FCC UNIT

Abstract of the Disclosure

A pressurized closed-cyclone catalyst disengaging apparatus for use in an FCC unit. A closed-cyclone apparatus of the present invention independently pressurized in the absence of a disengager vessel has a line for venting stripping steam and hydrocarbon vapor from a catalyst stripping stage to a catalyst disengaging stage for rapidly disengaging catalyst particles from an FCC reaction hydrocarbon effluent.

Field of the Invention

The present invention relates to a fluid catalytic cracking (FCC) unit, and more particularly a pressurized, closed-cyclone apparatus useful in an FCC unit.

Background of the Invention

The introduction of high activity, high selectivity catalysts in fluidized catalytic cracking (FCC) has significantly decreased the reaction time needed to obtain desired products. Desirable cracking reactions are known to occur in an essentially plug-flow, short residence time regime of a riser. As a result, attention has been focused on achieving a rapid post-riser separation of catalyst and quenching of product vaporsto minimize undesirable side reactions. (e. g. thermal cracking and hydrogen transfer) which reduce yield.

Recent developments in post-riser catalyst separation known as the closed or direct-connected cyclone technology are disclosed in Haddad et al. U. S. Patent 4,909,993 which is hereby incorporated herein by reference. Briefly, staged cyclone separators are enclosed in a disengagement vessel and effluent from the riser is fed directly to the primary cyclone. Gaseous effluent from the primary cyclone is directly introduced to a secondary cyclone (and any additional cyclone stages) which are directly connected by conduit without any additional reaction residence time in the disengagement vessel. The conduits (or plenums) between stages have vents to permit stripping steam to enter. The separated catalyst particles travel down diplegs of the cyclone stages for accumulation in the disengagement vessel and feed to a catalyst regeneration stage. See also Peterson U. S. Patent 5,370,844 which is hereby incorporated herein by reference.

Heretofore, as far as applicants are aware, the cyclone stages have not been pressurized independently from the disengagement vessel in which they have been housed. To permit the introduction of stripping steam into the

cyclone plenum inlets from the disengagement vessel, the cyclone stages have been maintained totally enclosed within the pressurized catalyst disengagement vessel.

Upson et al., "Unit Design and Operational Control: Impact on Product Yields and Product Quality", in Fluid Catalytic Cracking: Science and Technology, Studies in Surface Science and Catalysis, Vol. 76, Elsevier Science Publishers B. V., 1993, p. 391; and Avidan et. al., Oil & Gas Journal, January 8, 1990, pp. 14-32; purport to describe an evolution of FCC process units.

U. S. Patent 4,455,220 to Parker et al. describes the separation of catalyst and hydrocarbon vapors in a cyclone zone attached to the discharge of a riser wherein a vortex stabilizing means separates the cyclone zone from a stripping zone and allows stripping gas in the stripping zone to be passed therethrough to the cyclone zone countercurrent to the downward flow of the catalyst.

U. S. Patent 4,721,603 to Krug et al. describes a specific baffle arrangement within a catalytic reactor which improves the separation of gaseous hydrocarbon reaction products from catalyst within the reactor vessel.

Summary of the Invention

A pressurized, externally disposed, closed-cyclone apparatus of the present invention has a vent line for introducing stripping steam and hydrocarbon vapor from a catalyst stripping stage to a catalyst disengaging stage, and diplegs for discharging separated catalyst particles from the catalyst disengaging stage to the stripping stage for rapidly disengaging catalyst from the cracked hydrocarbon effluent of an FCC riser.

As one embodiment, the present invention provides an apparatus for disengaging catalyst particles from a cracked hydrocarbon gas in a fluidized

catalytic cracking (FCC) unit. A pressure-containing primary cyclone is provided for receiving cracked hydrocarbon gas containing suspended catalyst particles from an FCC riser and disengaging a major portion of the catalyst particles therefrom to form a gas stream of reduced catalyst content. A plenum is provided for passing the gas stream from the primary cyclone to pressure-containing secondary cyclone(s) adapted to disengage residual catalyst particles and form an essentially catalyst-free hydrocarbon stream. Primary and secondary diplegs are provided for gravity-feeding disengaged catalyst particles from the respective primary and secondary cyclones into a stripping vessel. A steam distributor is provided for countercurrently contacting catalyst particles in the stripping vessel with steam. Lines are provided for venting steam and hydrocarbon vapors from the stripping vessel to the plenum and for withdrawing stripped catalyst particles from the stripping vessel.

In a preferred embodiment, the cyclones have refractory linings comprising high density vibration cast refractory. The primary cyclone is preferably supported atop the stripping vessel with the primary dipleg descending from the primary cyclone coaxially into the stripping vessel. The stripping vessel preferably includes an annular catalyst disengagement zone between a stripper bed and an outlet to the steam venting line. The stripping vessel preferably includes a baffled section between the bottom of the primary dipleg and the steam injection distributor. The secondary dipleg is preferably connected to the stripping vessel adjacent the bottom of the primary dipleg. The primary and secondary cyclones have an exterior surface exposed to ambient conditions.

As another embodiment, the present invention provides a method for disengaging catalyst particles from a cracked hydrocarbon gas in a fluidized catalytic cracking (FCC) unit. As a first step, cracked hydrocarbon gas containing catalyst particles is passed involutely through a pressurized

primary cyclone to disengage catalyst particles and form a catalyst-lean stream. As a second step, the catalyst-lean stream is passed from the primary cyclone into a sealed plenum. Steam is introduced into the stripper to countercurrently contact the catalyst particles. Steam and hydrocarbon vapors from an overhead vapor space in the stripper are passed into the plenum. The catalyst-lean stream, steam and hydrocarbon vapors from the plenum are passed involutely through a pressurized secondary cyclone(s) to disengage residual catalyst particles and form an essentially catalyst-free stream. The disengaged catalyst particles from the secondary cyclone are passed into the stripper. Stripped catalyst particles from the stripper are recovered.

The primary and secondary cyclones are preferably operated with walls exposed to ambient conditions. The primary cyclone is preferably supported coaxially atop the stripping vessel. The stripping vessel is preferably supported coaxially atop or adjacent a regenerator and the recovered catalyst particles are passed from the stripper into the regenerator.

Brief Description of the Drawings

Fig. 1 is a schematic representation of a side view of an embodiment of an FCC reaction unit showing a pressurized, closed-cyclone apparatus of the present invention externally mounted to the side of a regeneration vessel.

Fig. 2 is a schematic representation of a side view of another embodiment of an FCC reaction unit showing the pressurized, close-cyclone apparatus externally mounted from above the regeneration vessel.

Detailed Description of the Invention

An externally mounted, closed-cyclone separation apparatus of the present invention is independently pressurized to permit elimination of an enclosing disengagement vessel without decreasing the efficiency of catalyst disengagement and recovery of hydrocarbons from spent catalyst particles.

Referring to Figs. 1-2, wherein like numerals refer to similar parts, embodiments **10**, **100** of a fluidized catalytic cracking (FCC) reaction unit of the present invention have a pressurized, two-stage closed-cyclone disengagement apparatus **12** mounted externally with respect of a regeneration vessel **14** either from the side as seen in Fig. 1 or from above as seen in Fig. 2 to rapidly disengage catalyst particles from the riser **16** effluent. Use of the present cyclone apparatus **12** minimizes undesirable side reactions to maximize yield of desired products without lowering the efficiency of catalyst disengagement. In addition, the relatively high cost and complexity of installing and maintaining cyclones within an enclosing disengagement vessel in the prior art is eliminated.

The cracking of heavy hydrocarbons such as petroleum oils into lighter hydrocarbons such as gasoline, light cycle oil (LCO), and olefins by FCC is well known. Briefly, the process employs finely divided fluidized catalyst particles which are continuously circulated between a reaction zone in the riser **16** and a regeneration zone in the regeneration vessel **14**. In the riser **16**, long chain hydrocarbons are split into shorter chain molecules and carbon deposits form on the catalyst particles. Carbon-coated catalyst, also referred to in the art as spent catalyst, is then disengaged from the effluent hydrocarbons by the closed-cyclone apparatus **12** and circulated to a regeneration zone in the regeneration vessel **14**. In the regeneration vessel **14**, carbon deposits are burned in the presence of air introduced therein via an air sparger **17** to produce heat and a carbon dioxide-containing exhaust gas, and regenerate the catalyst. Hot, regenerated catalyst is circulated back to the riser **16** via standpipe **18** wherein the heat of regeneration is carried to the reaction zone.

A cracked hydrocarbon stream essentially free of catalyst is withdrawn from the cyclone apparatus **12** for the recovery of heat and hydrocarbon products. Hot exhaust gas produced by catalyst regeneration is preferably

separated from the entrained catalyst by a disengagement stage comprising cyclones **19** internally disposed in the regeneration vessel **14**. The cyclones **19** are operated conventionally and have diplegs **20** extending into a bed **22** of regenerated catalyst to seal the diplegs **22** from exhaust gas. Gas discharged from the cyclones **19** is withdrawn for the recovery of heat (e. g. steam generation) prior to disposal.

A fluidized hydrocarbon/catalyst reaction medium is maintained in a reaction zone of the riser **16** at an elevated temperature and pressure for a suitable length of time necessary to maximize the desired mix of cracked hydrocarbon products in the reaction effluent. In addition, the riser reaction zone is preferably maintained in a plug-flow mass transport regime and backmixing is minimized as the reaction medium circulates up the riser **16** for discharge into the present closed-cyclone catalyst disengagement apparatus **12**.

The riser **16** is maintained in pressurized fluid communication with a primary disengagement stage of the present closed-cyclone disengagement apparatus **12** via a conduit **23** transversely oriented thereto. In the primary stage, the riser effluent stream **23** is introduced to an upper end of an involutely-shaped primary cyclone **24** wherein a major portion of the suspended catalyst is conventionally disengaged from the riser effluent stream **23** and removed by gravity down a dipleg **25** to a catalyst accumulation and stripping zone.

Discharged gas from the primary cyclone **24** is passed through a discharge duct **26** and gathered into a plenum **28** disposed at an inlet to a secondary disengagement stage comprising one or more secondary cyclones **30**. Gas from the plenum is roughly evenly distributed to an upper involute end of the secondary cyclone(s) **30** via a duct **32**. The secondary cyclone(s) **30** substantially disengages all the remaining suspended catalyst particles from the discharge gas **26**. Separated catalyst particles are subsequently

removed by gravity down a dipleg **34** to the catalyst accumulation and stripping zone.

The diplegs **25**, **34** have openings (not shown) extending below an upper surface of a spent catalyst bed **38** accumulated in a stripping vessel **40** to seal the diplegs **25**, **34** from stripping steam introduced via one or more steam spargers **39**. In a preferred arrangement, the stripping vessel **40** is integrally connected to the primary cyclone **24** so that the dipleg **25** is coaxially received therein. Using such an arrangement, the cyclone apparatus **12** and stripping vessel **40** together can be positioned to maximize layout efficiency of the reaction units **10**, **100** without the necessity of housing in a disengagement vessel. However, the stripping vessel could be positioned to the side of the cyclone **24** and the dipleg **25** could be inclined in a fashion similar to cyclone **30** and dipleg **34**. Steam is preferably countercurrently distributed through the bed **38** to enhance the stripping of hydrocarbons from the catalyst particles. To this end, several steam distribution baffles **42** are preferably disposed within the catalyst bed **38** to ensure suitable countercurrent distribution of steam therein.

In the practice of the present invention, a vent line **44** is used to introduce a stream comprising hydrocarbon vapor and steam accumulating in the stripping vessel **40** to the secondary cyclone stage of the present closed-cyclone apparatus **12**. The vent line **44** preferably extends from an upper end **46** of the vessel **40** to the plenum **28** to facilitate disengagement of the catalyst particles from the steam/hydrocarbon mixture in the secondary cyclone(s) **30**. A discharge gas which is substantially free of suspended particles is withdrawn from the secondary cyclone(s) **30** via duct(s) **48**. Catalyst particles which have been substantially stripped of volatile hydrocarbons are circulated to the regenerator vessel **14** via standpipe **50**.

In an alternative embodiment **100** of the present invention as seen in Fig. 2, the present closed-cyclone apparatus **12** in combination with the

stripping vessel **40** can be mounted externally atop the catalyst regenerator **14**. Catalyst accumulating in the stripping vessel **40** is preferably passed into the regenerator **14** through a standpipe **104** extending therein. The standpipe **104** can extend into a spent catalyst distributor **105** connected to a gas inlet line **106** so that catalyst particles from the standpipe **104** are fluidized by the gas.

Catalyst in the regenerator **14** can be cooled by one or more external bayonet type exchangers **110** as known in the art. Catalyst solids enter the exchanger **110** through line **112** for heat exchange with a cooling medium flowing through internal tubes (not shown) such as boiler feedwater to generate steam. The exchanger **110** is vented to the regenerator **14** via line **114**. The cooled catalyst solids are discharged to the regenerator **14** via standpipe **116**. Cooled, regenerated catalyst is circulated back to the riser **16** via standpipe **118**. The standpipe **118** has a catalyst flow control valve **120** to maintain a suitable catalyst circulation rate to the riser **16**. Exhaust gas is withdrawn via line **122**.

The closed-cyclone apparatus **12** of the present invention, pressurized independently from any disengagement vessel, is preferably made by pressure vessel techniques used for withstanding the stresses of a pressurized fluid at elevated operating temperatures and erosion due to high velocity particulate flows. As a result, the cyclone walls are preferably internally lined with refractory. Both cold wall and hot wall refractory lining designs can be used. A suitable hot wall construction includes an insulated exterior surface having an approximately 2.5 cm thick interior erosion resistant refractory lining supported in hexsteel. A preferred cold wall construction includes an uninsulated exterior surface and an interior surface lined with a thicker vibration cast refractory up to about 13 cm (5 inches) thick.

EXAMPLE

An equipment cost estimation is made to compare the costs of an internal cyclone system (and disengager vessel) against an external cyclone arrangement (including stripping vessel) of the present invention designed for operation at a pressure in the range of 15-25 psi above atmospheric. Basis for sizing the equipment is a 25,000 barrels per day FCC unit charge rate. Standard cost estimating techniques are employed and the results are presented in the Table with a ±25% accuracy.

Table

Equipment	Internal cyclone (Prior art)		External Cyclone	
	Size (dia. m)	Cost (US$)	Size (dia. m)	Cost (US$)
Disengager	5.30	951,500	-	-
Stripper	-	-	1.83	220,000
Primary cyclone	1.47	300,000	2.03	636,000
Secondary cyclones	1.42		1.47	
Total		1,251,500		856,000

The use of externally disposed cyclones permits cold wall design to be used as well as a thicker refractory lining for longer in-service operation between maintenance replacement. Cyclone lining erosion is typically a primary limitation to FCC unit run length. In addition, external placement of the cyclones reduces maintenance costs since the confined work space problems posed by the disengager vessel are eliminated.

The present FCC closed cyclone apparatus is illustrated by way of the foregoing description and examples. The foregoing description is intended as a non-limiting illustration, since many variations will become apparent to those skilled in the art in view thereof. It is intended that all such variations within the scope and spirit of the appended claims be embraced thereby.

Claims:

1. Apparatus for disengaging catalyst particles from a cracked hydrocarbon gas in a fluidized catalytic cracking (FCC) unit, comprising:

a pressure-containing primary cyclone for receiving cracked hydrocarbon gas containing suspended catalyst particles from an FCC riser to disengage a major portion of the catalyst particles therefrom and form a gas stream of reduced catalyst content;

a plenum for passing the gas stream from the primary cyclone to pressure-containing secondary cyclone(s) adapted to disengage residual catalyst particles and form an essentially catalyst-free hydrocarbon stream;

primary and secondary diplegs for gravity-feeding disengaged catalyst particles from the respective primary and secondary cyclones into a stripping vessel;

a gas distributor for countercurrently contacting catalyst particles in the stripping vessel with steam or other gas;

a line for venting steam or other gas and hydrocarbon vapors from the stripping vessel to the plenum;

a line for withdrawing stripped catalyst particles from the stripping vessel.

2. The apparatus of claim 1, wherein the cyclones have refractory linings comprising high density vibration cast refractory.

3. The apparatus of claim 1, wherein the primary cyclone is supported atop the stripping vessel with the primary dipleg descending from the primary cyclone coaxially into the stripping vessel.

4. The apparatus of claim 3, wherein the stripping vessel is supported atop a catalyst regenerator with a standpipe descending from the stripping vessel coaxially into the regenerator.

5. The apparatus of claim 3, wherein the stripping vessel includes an annular catalyst disengagement zone between a stripper bed and an outlet to the stripper vent line.

6. The apparatus of claim 3, wherein the stripping vessel includes a baffled section between a bottom of the primary dipleg and the steam injection distributor.

7. The apparatus of claim 3, wherein the secondary dipleg is connected to the stripping vessel adjacent a bottom of the primary dipleg.

8. The apparatus of claim 1, wherein the primary and secondary cyclones have an exterior surface exposed to ambient conditions.

9. A method for disengaging catalyst particles from a cracked hydrocarbon gas in a fluidized catalytic cracking (FCC) unit, comprising the steps of:

passing cracked hydrocarbon gas containing catalyst particles involutely through a pressurized primary cyclone to disengage catalyst particles and form a catalyst-lean stream;

passing the catalyst-lean stream from the primary cyclone into a sealed plenum;

passing the disengaged catalyst particles from the primary cyclone into a stripper;

introducing steam or other gas into the stripper to countercurrently contact the catalyst particles;

passing the steam or other gas and hydrocarbon vapors from an overhead vapor space in the stripper into the plenum;

passing the catalyst-lean stream, steam or other gas and hydrocarbon vapors from the plenum involutely through a pressurized

secondary cyclone(s) to disengage residual catalyst particles and form an essentially catalyst-free stream;

passing the disengaged catalyst particles from the secondary cyclone into the stripper;

recovering stripped catalyst particles from the stripper.

10. The method of claim 9, wherein the primary and secondary cyclones are operated with walls exposed to ambient conditions.

11. The method of claim 9, comprising supporting the primary cyclone coaxially atop the stripping vessel.

12. The method of claim 11, comprising supporting the stripping vessel coaxially atop or adjacent a regenerator and passing the catalyst particles recovered from the stripper into the regenerator.

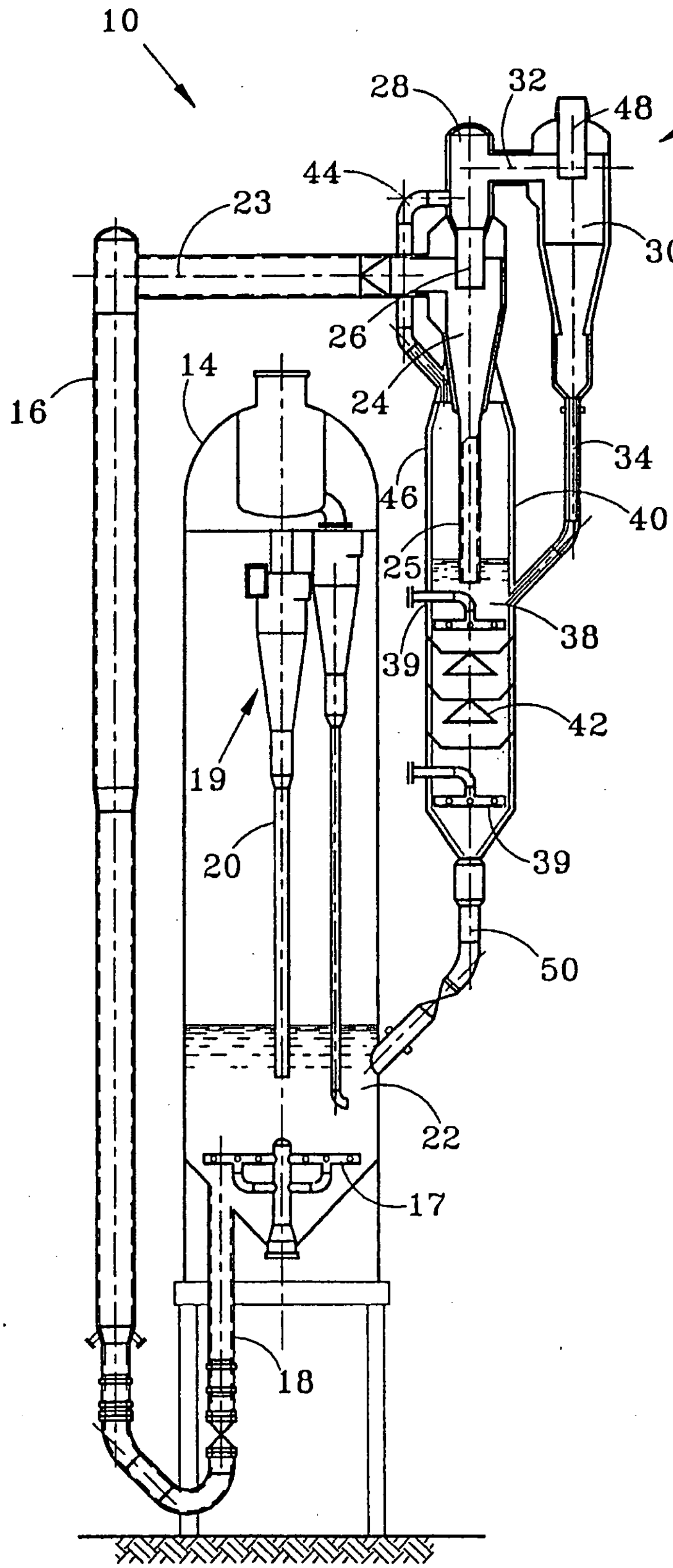
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FIG. 1

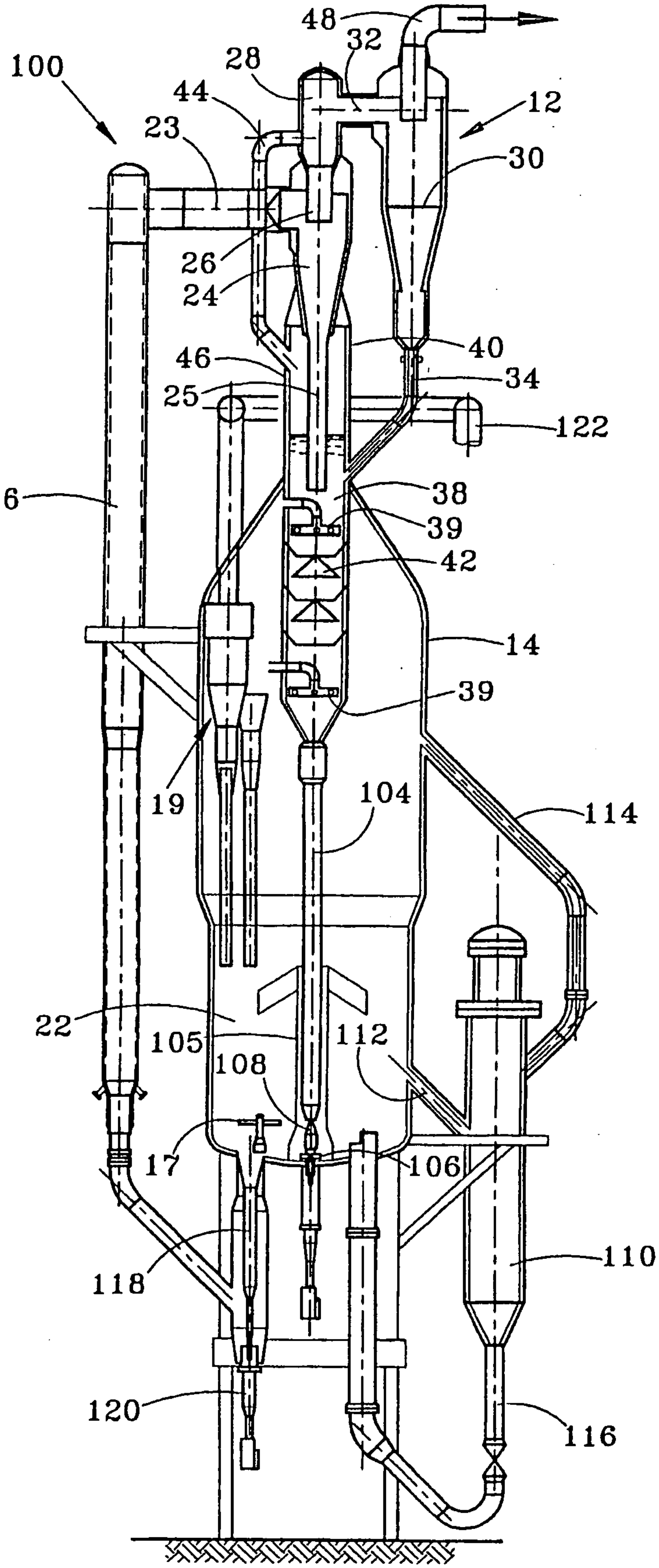

FIG. 2

Kirby, Eades, Gale, Baker